

# **QUANTIFYING CHANGES IN AFL PLAYER GAME DEMANDS USING GPS TRACKING**

**2007 AFL SEASON**

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## Table of Contents

Executive Summary .....	3
Methods .....	5
Statistical Analysis .....	6
GPS Accuracy .....	6
Results .....	7
Work .....	8
Movement Pattern Profile .....	14
Time in Speed Zones .....	16
Rotations .....	17
Workloads by Team .....	20
Workloads Across the Season .....	21
NAB Cup (Preseason Competition) .....	22
Key Work Measures .....	23
Discussion .....	24
Comparisons between 2007 and 2006 AFL seasons .....	24
Comparison Between Positions .....	24
Rotations .....	24
Workloads Between AFL Venues .....	25
Workloads Across the Season .....	25
Workloads Between Teams .....	25
NAB Cup .....	26
Key Work Measures .....	26
Conclusions .....	27
Future Directions .....	28
Attachment A: GPS Analysis Definitions .....	29
References .....	31

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## **Executive Summary**

This research follows on from previous investigations into the demands of the elite level AFL competition based on GPS data collection by the same researchers in 2005 and 2006.

Fourteen clubs participated in this research with a total of 745 GPS game files captured in the 2007 Premiership Season and NAB Cup.

Results showed a significant increase in game intensity compared to previous years (4.3% greater than 2006 and 10% greater than 2005), with nomadic players completing significantly more work at a greater intensity than fixed forwards and defenders.

Those players who were rotated more often were able to maintain a higher game intensity; however no substantial changes in workload trends existed across the course of the Premiership season.

Interestingly, it was the least successful teams who completed the most work across the season highlighting the importance of technical characteristics in game outcomes.

This research shows that the playing demands of elite AFL footballers continues to change as the game evolves, with players now required to undertake similar volumes of work but at greater intensities than in 2005 and 2006.

## Introduction

Monitoring the physical demands of players in the Australian Football League (AFL) is an important part of player preparation. A thorough understanding of a player's physical load assists in determining adequate physical preparation and minimising the risk of injury. Global positioning systems (GPS) monitoring also provides a detailed understanding of player movements and can assist teams from a tactical view point.

While the running demands of AFL have been quantified through the use of GPS analysis (Wisbey & Montgomery 2005, 2007), the small sample size restricted the breadth and depth of practical outcomes. AFL is a highly dynamic and intermittent game with rule changes and tactical changes influencing particular aspects of the game such as increased game speed, player rotation frequency and the period of time the ball is in play (Norton, 2007).

All sixteen AFL teams now use GPS systems to quantify game and training performance. The benefits of GPS include allowing conditioning staff to quantify speed and movement profiles of multiple players easily throughout the course of a game, without the need for manual tracking.

In 2005, the first comprehensive report of AFL game demands using GPS data captured during competition was produced from 80 GPS files (Wisbey & Montgomery, 2005). This work was expanded for the 2006 season to capture 244 GPS files (Wisbey & Montgomery, 2007). The 2006 report concluded:

- Minimal changes had occurred in player demands between the 2005 and 2006 seasons.
- A player's workload is largely dependant on the team and playing position.
- Differences in the playing demands for midfielders exist not only in terms of an increased workload, but also in the manner that the work is undertaken.
- The size and shape of AFL grounds had no substantial relationship with the running requirements of players during a game.

The 2006 findings generally supported the outcomes of the 2005 GPS research:

- Total running distances are substantially lower than previously reported.
- The intensity of the work rather than total running distance separated midfielders from other playing positions. Midfielders undertook a greater amount of continual running with more surges in the higher speed zones.
- The intermittent nature of AFL is a key factor in fatigue, recovery and injuries.
- There is a linear relationship between total work and number of possessions obtained.
- The Exertion Index provided a valid estimate of overall game demands.

Although the number of GPS samples increased from 2005-2006, the total number in 2006 was still relatively small (~3.3%) given the number of games played across the whole season. For this reason, the 2007 GPS research set out to compare game trends across the season and incorporate a comprehensive analysis of playing profiles.

The key goals of the 2007 research were to investigate:

- The 2007 game demands compared with the 2005 and 2006 seasons using the GPS analysis.

- Differences in playing requirements between AFL venues (grounds).
- The relationship between player demands and the number of player rotations.
- The variations in playing demands between teams, and the relationship to team performance.
- Player demands across the course of the season.
- Player demands between the Premiership Season (where standard rules apply) and the NAB Cup pre-season competition (where some modified rules apply).

## Methods

Elite AFL footballers (n=203) from fourteen of the sixteen AFL clubs were tracked using GPS Systems (GPSports, Canberra, Australia) during the 2007 AFL season. Players were assigned to three major positional groups nominated by their respective clubs – i.e. fixed forwards, nomadic and fixed defenders.

GPS units were fitted to the upper back of each player using a purpose built supportive harness. For the purpose of this research, analysis was restricted to ten players in each game for each team throughout the season. In total, 745 game files were captured.

The GPS units captured data at 1 Hz throughout the duration of each game, and recorded speed, altitude, heart rate, latitude and longitude. Where no satellites were found by the GPS unit during the course of the game, data for this period was omitted.

Each participating club was responsible for fitting the units to their players during their selected games and the downloading of data to PC. Data was then sent to the researchers. All game data was exported to Microsoft Excel, before analysis with custom-built GPS software (Sports Tracker Analysis v1.3, FitSense Australia). All GPS game data was stored with accompanying demographic data for each player. This data was made up of individual player game possession statistics (rotations, kicks, handballs, marks, and total possessions), player position, team, opposition, venue, playing duration and date. All playing time was analysed. Non-playing periods (quarter breaks and interchange periods) were omitted from the analysed data.

All game files were analysed using a number of steady state and movement pattern variables:

- Total distance (km)
- Average speed (km/hr)
- Exertion index
- Exertion index per minute
- Time spent in speed zones (min:sec)
- Number of surges over specified speeds
- Longest continuous time above specified speeds (seconds)
- Maximal speed (km/hr)
- Acceleration / deceleration profile

A brief explanation of each variable is outlined in Attachment A.

### ***Statistical Analysis***

Upon receiving the GPS game files (n=745), the researchers omitted games with a playing duration of less than 60 minutes. Files were then inspected for obvious errors and outliers and 'cleaned' as required. The final number of data files fully analysed was n=53 for the NAB Cup and n=629 for the Premiership Season.

Statistical analysis was performed with the SPSS software package (v13.0). A Pearson two tailed correlation was used to assess the relationship between variables with a significance of  $p < 0.01$ . Comparisons of variables between positions and years was performed using a one-way ANOVA, with a significance level of  $p < 0.05$ . Where significant differences were established a Bonferroni post hoc comparison was used.

Magnitudes of effect sizes (ES) were assessed using the criteria of:  $< 0.2$  trivial, 0.2-0.6 small, 0.6-1.2 moderate, 1.2-2.0 large and  $> 2.0$  very large. A substantial change was accepted when there was  $> 75\%$  likelihood that the true value of the standardised mean difference was greater than the smallest worthwhile (substantial) change (Hopkins 2000).

### ***GPS Accuracy***

The GPSports units are claimed by the manufacturer to be 99% accurate in continuous straight line running, and 96-97% accurate in a dynamic team sport situation with rapid changes of speed and direction (GPSports, 2005). However, a study by Edgecombe and Norton (2006) showed that within an AFL game, the mean error of the GPSports Systems when compared to measured distance was 4.8%. This error was due to an overestimation of distance from the GPS system compared to the actual measured distance. The study reported that the GPS systems had a relative Technical Error of Measurement (TEM) of 5.5%, indicating the technology can be used to quantify speed and distance in the AFL.

GPS technology appears more reliable than traditional manually coded time-motion analysis. Further work is required to clarify the reliability and validity of GPS monitoring of movement patterns in the dynamic chaotic environment of AFL football.

## Results

The 629 files from the 2007 Premiership Season comprised the following number of files per ground:

- AAMI Stadium, Adelaide (n=122)
- Aurora Stadium, Launceston (n=24)
- GABBA, Brisbane (n=71)
- Gold Coast (n=16)
- Manuka Oval, Canberra (n=12)
- Melbourne Cricket Ground, Melbourne (n=206)
- Sydney Cricket Ground, Sydney (n=33)
- Skilled Stadium, Geelong (n=28)
- Subiaco Oval, Perth (n=93)
- Telstra Dome, Melbourne (n=17)
- Telstra Stadium, Sydney (n=7)

To directly compare data from 2005 and 2006, a more stringent data filtering method was used, resulting in the removal of all files with a playing duration of less than 80 minutes. This left n=561 files for the comparative seasonal and positional analysis. This filtering was also applied in the 2005 and 2006 data, allowing a direct comparison between seasons. These files comprised the following number of files per playing positions:

- Forwards (n=39)
- Nomadic (n=493)
- Defenders (n=29)

## Work

Work measures comparing data collected in the 2005, 2006 and 2007 Premiership Seasons are shown in Table 1, while individual positional workload data is shown in Table 2. The distribution of Exertion Index across the whole sample group is displayed in Figure 1, and Exertion Index per Minute in Figure 2.

Small, but statistically significant, changes exist between the 2007 data and the 2005/2006 data with mean speed and exertion index per minute increasing and total time decreasing.

There was a small increase in exertion index per minute in 2007 compared to 2006 (ES=0.21). There was also a small increase in average speed from 2007 compared to 2006 (ES=0.45).

The effect size of the exertion index between nomadic and forwards (ES=0.97), and nomadic and defender (ES=1.01) showed a moderately substantial difference. The workload measures of average speed, exertion index and exertion index per minute were significantly greater for those playing in a nomadic position compared to forwards and defenders. The total playing duration for nomadic players was also significantly less than those playing in forward or defender positions.

**Table 1.** Comparison of main work variables between seasons (mean  $\pm$  SD).

Work Variable	2007 Mean Values (n=561 files)	2006 Mean Values (n=244 files)	2005 Mean Values (n=80 files)
Total Distance (km)	12.42 $\pm$ 1.58	12.51 $\pm$ 1.71	12.45 $\pm$ 1.65
Average Speed (km·hr <sup>-1</sup> )	7.18 $\pm$ 0.81♥	6.78 $\pm$ 0.94	6.76 $\pm$ 0.67
Total Time (min)	104:19 $\pm$ 12:16♥	111:51 $\pm$ 14:13	111:01 $\pm$ 13:50
Exertion Index	125.6 $\pm$ 21.9	122.7 $\pm$ 24.0	121.0 $\pm$ 20.44
Exertion Index per Minute	1.21 $\pm$ 0.22♥	1.16 $\pm$ 0.25	1.10 $\pm$ 0.18
Efficiency (Exertion Index per Possession)	8.67 $\pm$ 3.57	8.77 $\pm$ 4.22	8.23 $\pm$ 3.35
Max Speed (km·hr <sup>-1</sup> )	30.06 $\pm$ 6.74	29.70 $\pm$ 2.16	30.25 $\pm$ 1.89

♥ = Significantly different from 2005 and 2006 (p<0.05).

The exertion index per minute was 4.3% higher in 2007 compared with 2006. This finding reflected the combination of a 6.7% reduction in playing time and a 2.3% increase in exertion index.



**Table 2.** Work variables by position (mean  $\pm$  SD).

	<b>Forward</b> (n=39)	<b>Nomadic</b> (n=493)	<b>Defender</b> (n=29)
Total Distance (km)	11.66 $\pm$ 1.58	12.52 $\pm$ 1.57 <sup>*</sup>	11.66 $\pm$ 1.17
Average Speed (km/hr)	6.40 $\pm$ 0.61	7.29 $\pm$ 0.76 <sup>*</sup>	6.36 $\pm$ 0.83
Total Time (min)	109.48 $\pm$ 11.97	103.58 $\pm$ 12.17 <sup>*</sup>	110:08 $\pm$ 11:34
Exertion Index	108.4 $\pm$ 18.7	127.9 $\pm$ 21.4 <sup>*</sup>	108.4 $\pm$ 16.8
Exertion Index per Minute	1.00 $\pm$ 0.16	1.24 $\pm$ 0.21 <sup>*</sup>	1.00 $\pm$ 0.21
Efficiency (Exertion Index per Possession)	9.81 $\pm$ 3.53	8.65 $\pm$ 3.62	7.12 $\pm$ 1.64
Max Speed (km/hr)	29.59 $\pm$ 1.30	30.13 $\pm$ 7.16	29.57 $\pm$ 1.71

\* = Significantly different from all other positions. ♠ = Significantly different from defenders (p<0.05). ♥ = Significantly different from forwards (p<0.05).

Similar to 2006 and 2005, workloads for nomadic players (previously categorised as midfielders) were moderately higher than for forwards and defenders. This observation is highlighted by a higher exertion index of 10.9%, and a higher exertion index per minute of 24% (average intensity).

**Table 3.** Work variable by AFL venue (mean  $\pm$  SD).

<b>Work Variable</b>	<b>AAMI Stadium</b> (n=122 files)	<b>GABBA</b> (n=71 files)	<b>MCG</b> (n=206 files)	<b>SCG</b> (n=33 files)	<b>Subiaco Oval</b> (n=93 files)
Total Distance (km)	12.40 $\pm$ 1.94	12.07 $\pm$ 1.90	12.05 $\pm$ 1.80	12.21 $\pm$ 3.31	12.02 $\pm$ 2.20
Average Speed (km·hr <sup>-1</sup> )	7.41 $\pm$ 0.80	7.11 $\pm$ 0.87	7.26 $\pm$ 0.81	7.10 $\pm$ 0.56	7.32 $\pm$ 0.94
Total Time (min)	100:58 $\pm$ 15:19	102:42 $\pm$ 15:20	100:15 $\pm$ 15:13	103:25 $\pm$ 30:20	99:46 $\pm$ 21:53
Exertion Index	127.3 $\pm$ 24.4	121.4 $\pm$ 25.0	123.0 $\pm$ 22.9	122.3 $\pm$ 32.6	122.3 $\pm$ 24.2
Exertion Index per Minute	1.27 $\pm$ 0.22	1.20 $\pm$ 0.24	1.24 $\pm$ 0.22	1.18 $\pm$ 0.16	1.25 $\pm$ 0.26

The results shown in Table 3 illustrate the key workload variables for each ground where 30 or more game files were collected.

No differences of significance existed across grounds. Likewise, there was no substantial correlation between playing demands on the ground and the size of the ground (length multiplied by width).

The only small difference was a higher Exertion Index at AAMI stadium compared with the GABBA (ES=0.24).

<b>Table 4.</b> Comparison between Nomadic players and midfielders average work values (mean $\pm$ SD).			
	<b>Nomadic 2007</b> (n=493)	<b>Midfielder 2006</b> (n=113)	<b>Midfielder 2005</b> (n=35)
Total Distance (km)	12.52 $\pm$ 1.57 *	13.24 $\pm$ 1.67	12.93 $\pm$ 3.70
Average Speed (km/hr)	7.29 $\pm$ 0.76	7.31 $\pm$ 0.77	6.98 $\pm$ 0.75
Total Time (min)	103:58 $\pm$ 12:17 #	109:55 $\pm$ 14:55	111:48 $\pm$ 32:12
Exertion Index	127.9 $\pm$ 21.4 *	136.7 $\pm$ 20.9	128.6 $\pm$ 38.1
Exertion Index per Minute	1.24 $\pm$ 0.21 ♥	1.26 $\pm$ 0.20	1.16 $\pm$ 0.16
Max Speed (km/hr)	30.13 $\pm$ 7.16	29.72 $\pm$ 2.42	30.2 $\pm$ 2.36
* = significant difference from 2006 (p<0.05), # = significant difference from 2005 and 2006 (p<0.05), ♥ = significant difference from 2005. (p<0.05).			

Total distance covered and total exertion index were lower in 2007 compared with 2006. The playing duration for 2007 was less than 2005 and 2006, while the exertion index per minute was higher in 2005, but similar to 2006 levels.

<b>Table 5.</b> Comparison of work values for Forwards between the 2005, 2006 and 2007 seasons (mean $\pm$ SD).			
	<b>Forwards 2007</b> (n=39)	<b>Forward 2006</b> (n=66)	<b>Forward 2005</b> (n=14)
Total Distance (km)	11.66 $\pm$ 1.58	12.17 $\pm$ 1.60	11.95 $\pm$ 1.93
Average Speed (km/hr)	6.40 $\pm$ 0.61	6.50 $\pm$ 0.87	6.49 $\pm$ 0.67
Total Time (min)	109.48 $\pm$ 11.97	113.41 $\pm$ 14.36	110:36 $\pm$ 15:08
Exertion Index	108.4 $\pm$ 18.7	115.2 $\pm$ 21.3	111.6 $\pm$ 23.0
Exertion Index per Minute	1.00 $\pm$ 0.16	1.03 $\pm$ 0.22	1.01 $\pm$ 0.19
Max Speed (km/hr)	29.59 $\pm$ 1.30	29.96 $\pm$ 1.68	30.4 $\pm$ 1.59

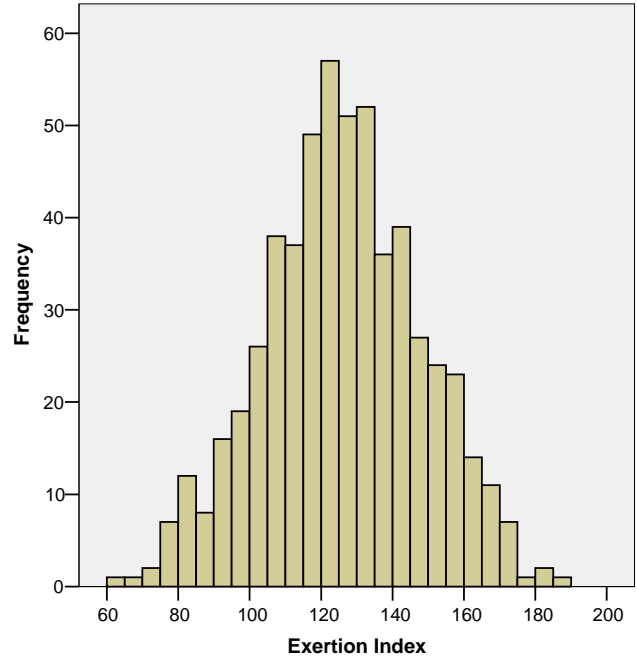
**Table 6.** Comparison of work values for Defenders between the 2005, 2006 and 2007 seasons (mean  $\pm$  SD).

	<b>Defender 2007</b> (n=29)	<b>Defender 2006</b> (n=56)	<b>Defender 2005</b> (n=31)
Total Distance (km)	11.66 $\pm$ 1.17	11.65 $\pm$ 1.29	12.12 $\pm$ 2.13
Average Speed (km/hr)	6.41 $\pm$ 0.78	6.05 $\pm$ 0.71	6.64 $\pm$ 0.67
Total Time (min)	110:08 $\pm$ 11:34	116.33 $\pm$ 11.73	110:18 $\pm$ 19:40
Exertion Index	108.4 $\pm$ 16.8	105.5 $\pm$ 16.8	116.6 $\pm$ 23.4
Exertion Index per Minute	1.00 $\pm$ 0.21 <sup>*</sup>	0.93 $\pm$ 0.18	1.07 $\pm$ 0.18
Max Speed (km/hr)	29.57 $\pm$ 1.71	29.91 $\pm$ 1.66	30.3 $\pm$ 1.49

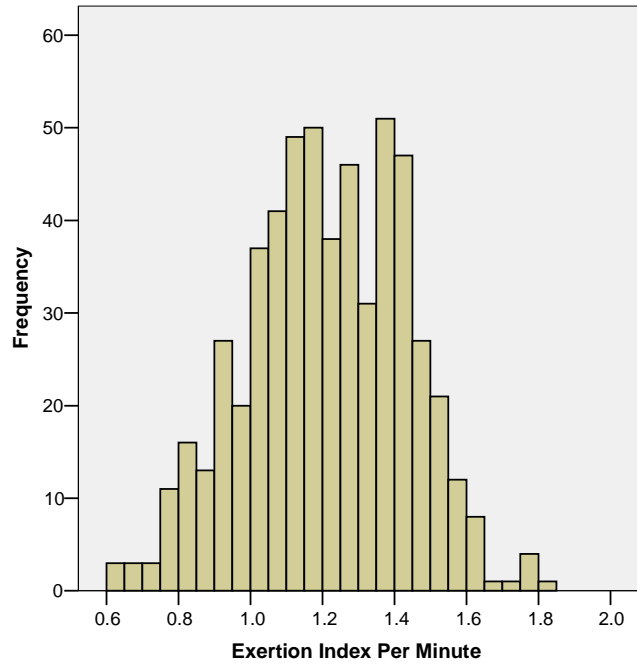
\* = significant difference from 2005 (p<0.05).

The exertion index per minute increased in 2007 from both 2006 (ES=0.36) and 2005 (ES=0.36).

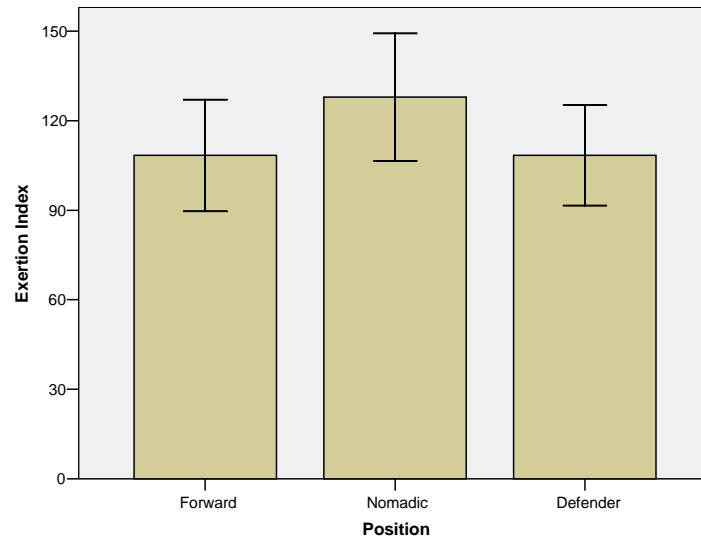
Figure 1 and 2 illustrate the spread of exertion index and exertion index per minute across the AFL.



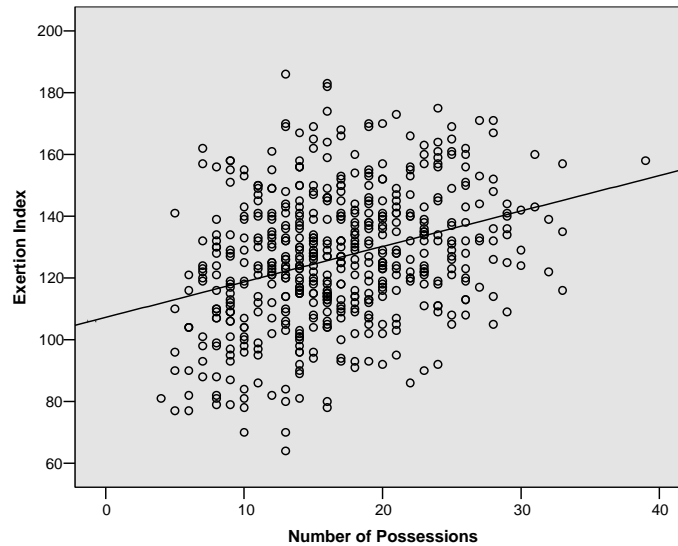
**Figure 1.** Histogram representing distribution of total Exertion Index across all positions in the 2007 season.



**Figure 2.** Histogram representing Exertion Index per Minute across all positions in the 2007 season.



**Figure 3.** Histogram representing total Exertion Index for individual positions.



**Figure 4.** Scatter plot representing player efficiency (Exertion Index v. Possessions) across all positions.

Figure 4 shows the relationship between Exertion Index and the number of possessions. A modest correlation ( $r=0.33$ ,  $p<0.01$ ) was observed with a higher exertion index associated with a higher number of possessions. Similarly, Exertion Index per minute was also modestly correlated with the number of possessions ( $r=0.31$ ,  $p<0.01$ ).

## Movement Pattern Profile

In 2007, there were fewer surges below 5 km/hr (walking) but more surges above 14 and 16 km/hr. Accompanying this was a substantial increase in the length of the longest efforts above 15 km/hr.

The positional data shows that the GPS profile of a nomadic player differs from other playing positions. This observation is in line with the findings of the 2005 and 2006 seasons. The main differences in 2007 were fewer walking breaks, more running efforts, longer efforts conducted at higher speeds and a higher volume of steady state running.

**Table 7.** Comparison of movement pattern variables between seasons (mean  $\pm$  SD).

Variable	2007 Season Mean Values (n=561)	2006 Season Mean Values (n=244)	2005 Season Mean Values (n=80)
Surges below 5 km·hr <sup>-1</sup>	345.77 $\pm$ 55.84 *	359.36 $\pm$ 61.86	365.15 $\pm$ 52.28
Surges above 14 km·hr <sup>-1</sup>	115.28 $\pm$ 24.83 #	110.04 $\pm$ 27.62	110.85 $\pm$ 24.66
Surges above 16 km·hr <sup>-1</sup>	83.13 $\pm$ 20.78 #	79.43 $\pm$ 21.65	77.31 $\pm$ 18.62
Surges above 18 km·hr <sup>-1</sup>	93.08 $\pm$ 19.61 ♥	90.09 $\pm$ 24.14	88.61 $\pm$ 20.20
Accelerations over 4 km·hr <sup>-1</sup> in 1sec	252.96 $\pm$ 41.05	251.23 $\pm$ 50.05	240.83 $\pm$ 43.15
Accelerations over 10 km·hr <sup>-1</sup> in 1sec	12.23 $\pm$ 5.26 ♥	11.52 $\pm$ 6.04	10.03 $\pm$ 4.35
Decelerations over 4 km·hr <sup>-1</sup> in 1sec	234.84 $\pm$ 39.00	232.70 $\pm$ 47.16	227.96 $\pm$ 42.58
Decelerations over 10 km·hr <sup>-1</sup> in 1sec	16.36 $\pm$ 5.96	15.71 $\pm$ 6.88	15.76 $\pm$ 5.30
LCT under 5 km·hr <sup>-1</sup> (min)	1:32 $\pm$ 0:44	2:00 $\pm$ 1:17	1:35 $\pm$ 0:44
LCT over 13 km·hr <sup>-1</sup> (sec)	22.88 $\pm$ 5.83	21.36 $\pm$ 5.18	21.59 $\pm$ 4.05
LCT over 15 km·hr <sup>-1</sup> (sec)	18.33 $\pm$ 4.61 *	17.32 $\pm$ 3.96	17.04 $\pm$ 3.18
LCT over 17 km·hr <sup>-1</sup> (sec)	14.75 $\pm$ 4.10	14.09 $\pm$ 3.39	14.31 $\pm$ 2.72
LCT over 20 km·hr <sup>-1</sup> (sec)	10.71 $\pm$ 3.86	10.12 $\pm$ 2.58	11.08 $\pm$ 2.80
Steady State Time above 8 km·hr <sup>-1</sup> (min)	24:04 $\pm$ 5:25	23:01 $\pm$ 5:55	22:38 $\pm$ 4:49

\* = significant difference from 2005 and 2006 (p<0.05). # = significant difference from 2006 (p<0.05). ♥ = significant difference from 2005 (p<0.05).

LCT = longest continuous time.

<b>Table 8.</b> Movement pattern profile values by position for the 2007 AFL season (mean $\pm$ SD).			
	<b>Forward</b> (n=39)	<b>Nomadic</b> (n=493)	<b>Defender</b> (n=29)
Surges Below 5km/hr	369.64 $\pm$ 58.02	342.07 $\pm$ 54.92 <sup>*</sup>	376.48 $\pm$ 52.69
Surges Above 14 km/hr	95.08 $\pm$ 18.37	117.73 $\pm$ 24.50 <sup>*</sup>	115.28 $\pm$ 24.83
Surges Above 16 km/hr	65.15 $\pm$ 15.45	85.28 $\pm$ 20.29 <sup>*</sup>	83.13 $\pm$ 20.78
Surges Above 18 km/hr	79.28 $\pm$ 18.49	95.09 $\pm$ 18.92 <sup>*</sup>	93.08 $\pm$ 19.61
Accelerations Over 4km/hr in 1sec	235.05 $\pm$ 39.54	255.19 $\pm$ 41.37 <sup>♥</sup>	252.96 $\pm$ 41.05
Accelerations Over 10km/hr in 1sec	11.33 $\pm$ 5.45	12.41 $\pm$ 5.27	12.23 $\pm$ 5.26
Decelerations Over 4km/hr in 1sec	218.13 $\pm$ 36.15	236.76 $\pm$ 39.21 <sup>♥</sup>	234.84 $\pm$ 39.00
Decelerations Over 10km/hr in 1sec	15.33 $\pm$ 5.27	16.61 $\pm$ 6.05 <sup>♠</sup>	13.45 $\pm$ 4.45
LCT Under 5 km/hr (min)	1:32 $\pm$ 0:39	1:30 $\pm$ 0:44 <sup>♠</sup>	1:54 $\pm$ 0:46
LCT Over 13 km/hr (sec)	20.03 $\pm$ 5.07	23.32 $\pm$ 5.84 <sup>*</sup>	19.28 $\pm$ 4.22
LCT Over 15 km/hr (sec)	16.33 $\pm$ 3.69	18.64 $\pm$ 4.67 <sup>*</sup>	15.76 $\pm$ 3.03
LCT Over 17 km/hr (sec)	13.69 $\pm$ 3.35	14.93 $\pm$ 4.19 <sup>♠</sup>	13.03 $\pm$ 2.57
LCT Over 20 km/hr (sec)	9.92 $\pm$ 2.66	10.90 $\pm$ 3.98 <sup>♠</sup>	8.62 $\pm$ 2.16
Steady State Time Above 8 km/hr (min)	19:00 $\pm$ 4:10	24:44 $\pm$ 5:16 <sup>*</sup>	19:48 $\pm$ 3:43

\* = Significantly different from all other positions (p<0.05). ♠ = Significantly different from defenders (p<0.05). ♥ = Significantly different from forwards (p<0.05).

## Time in Speed Zones

Table 9 shows the comparisons between 2005, 2006 and 2007 speed zone profiles.

**Table 9.** Comparisons of time in speed zones between seasons (mean  $\pm$  SD).

Time Zone	2007 Season Mean Values (n=561)	2006 Season Mean Values (n=244)	2005 Season Mean Values (n=80 files)
Time Under 6 km·hr <sup>-1</sup> (min)	58:47 $\pm$ 12:01 *	66:43 $\pm$ 14:56	66:28 $\pm$ 11:93
Time Under 8 km·hr <sup>-1</sup> (min)	68:33 $\pm$ 12:52 *	77:19 $\pm$ 16:09	76:46 $\pm$ 12:35
Time 8-10 km·hr <sup>-1</sup> (min)	7:19 $\pm$ 1:37	7:20 $\pm$ 1:33	7:27 $\pm$ 1:35
Time 10-12 km·hr <sup>-1</sup> (min)	7:55 $\pm$ 1:43	7:42 $\pm$ 1:49	7:41 $\pm$ 1:43
Time 12-14 km·hr <sup>-1</sup> (min)	6:44 $\pm$ 1:40	6:25 $\pm$ 1:46	6:19 $\pm$ 1:30
Time 14-16 km·hr <sup>-1</sup> (min)	4:58 $\pm$ 1:21 *	4:40 $\pm$ 1:27	4:32 $\pm$ 1:05
Time 16-18 km·hr <sup>-1</sup> (min)	3:11 $\pm$ 0:55 *	3:01 $\pm$ 0:58	2:50 $\pm$ 0:43
Time Over 18 km·hr <sup>-1</sup> (min)	5:39 $\pm$ 1:28	5:25 $\pm$ 1:49	5:24 $\pm$ 1:31
Time Over 25 km·hr <sup>-1</sup> (sec)	32.88 $\pm$ 16.99	32.13 $\pm$ 18.08	35.53 $\pm$ 17.12

\* = significant difference from 2005 and 2006 (p<0.05). # = significant difference from 2006 (p<0.05). ♥ = significant difference from 2005 (p<0.05).



Table 10 shows the comparison in the speed zone profiles between positions from the data collected in the 2007 Premiership Season.

**Table 10.** Time spent in speed zones by position during the 2007 AFL season (mean  $\pm$  SD).

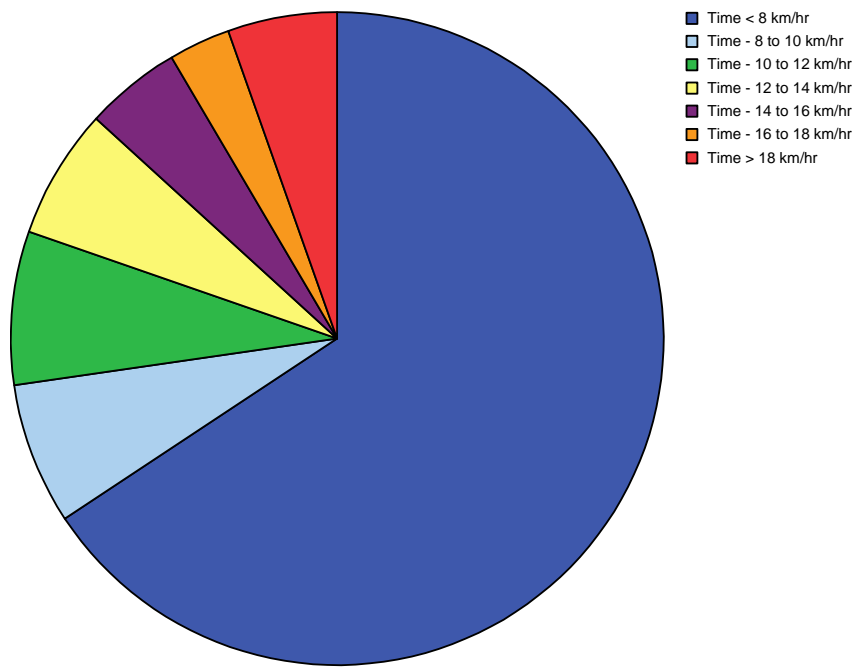
	<b>Forward</b> (n=39)	<b>Nomadic</b> (n=493)	<b>Defender</b> (n=29)
Time under 6 km/hr (min)	68:48 $\pm$ 10:29	57:22 $\pm$ 11:24 <sup>*</sup>	69:22 $\pm$ 12:44
Time under 8 km/hr (min)	80:02 $\pm$ 11:29	67:00 $\pm$ 12:09 <sup>*</sup>	79:26 $\pm$ 13:35
Time 8-10 km/hr (min)	6:31 $\pm$ 1:27	7:23 $\pm$ 1:37 <sup>♥</sup>	7:20 $\pm$ 1:30
Time 10-12 km/hr (min)	6:40 $\pm$ 1:35	8:04 $\pm$ 1:42 <sup>*</sup>	6:55 $\pm$ 1:21
Time 12-14 km/hr (min)	5:26 $\pm$ 1:19	6:54 $\pm$ 1:39 <sup>*</sup>	5:31 $\pm$ 1:11
Time 14-16 km/hr (min)	3:51 $\pm$ 0:55	5:07 $\pm$ 1:20 <sup>*</sup>	4:04 $\pm$ 0:59
Time 16-18 km/hr (min)	2:22 $\pm$ 0:38	3:17 $\pm$ 0:53 <sup>*</sup>	2:34 $\pm$ 0:53
Time over 18 km/hr (min)	4:36 $\pm$ 1:14	5:49 $\pm$ 1:25 <sup>*</sup>	4:19 $\pm$ 1:14
Time over 25 km/hr (sec)	31.72 $\pm$ 16.04	33.45 $\pm$ 17.01 <sup>♠</sup>	24.90 $\pm$ 16.31

\* = Significantly different from all other positions (p<0.05). ♠ = Significantly different from defenders (p<0.05). ♥ = Significantly different from forwards (p<0.05).

The GPS profile of a nomadic player differs from other playing positions. The difference is characterised by less time spent walking and more time spent at all running speeds.

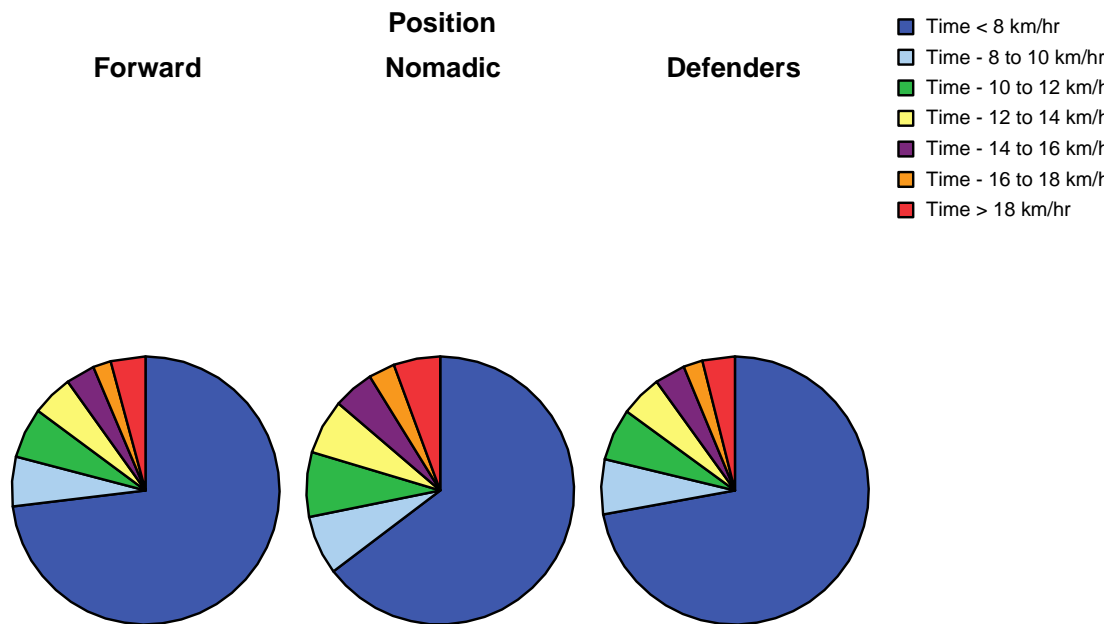
## Rotations

The number of rotations a player undertook during an AFL game was moderately correlated with exertion index per minute (r=0.45, p<0.01) and inversely correlated with playing duration (r=-0.49, p<0.01). This means that players with more rotations, and shorter playing duration (time on ground), were able to maintain a higher exertion index (work output). It is clear that the use of the interchange to rotate players facilitates players being able to maintain a higher work output.



**Figure 5.** Pie Chart representing the Time Spent in Speed Zones across all positions.

Figure 5 shows a pie chart of the speed zone profile from all data collected in the 2007 Premiership Season. This data is then presented by playing position in Figure 6.



**Figure 6.** Pie Chart showing the distribution of Time Spent in Speed Zones across positions.

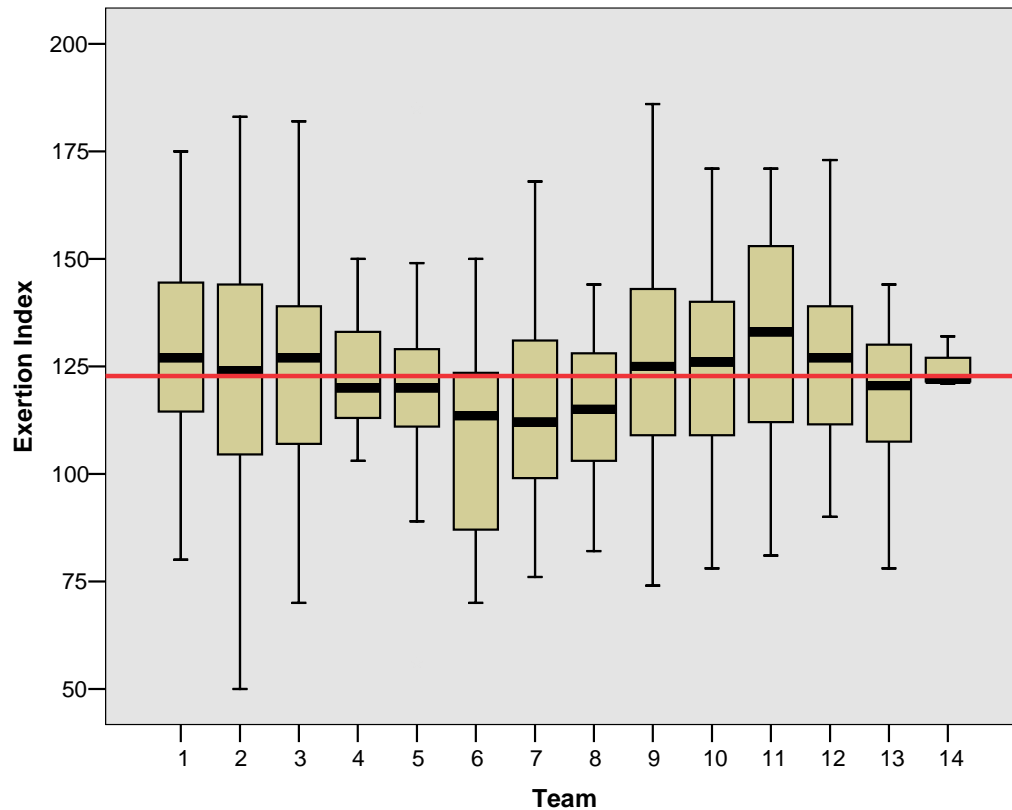
Variable	Effect Size
Time Under 6km/hr	0.58; small
Total Time (Playing Duration)	0.56; small
LCT Under 5km/hr	0.47; small
Average Speed	0.45; small
Exertion Index per Minute	0.21; small

**Table 11:** Rank order for key work variables between the 2006 and 2007 playing seasons. Only variables with a small substantial change or greater are listed. Time under 6km/hr, total time and LCT under 5 km/hr were all lower in 2007 than 2006 while average speed and exertion index per minute increased from 2006 to 2007.

There were only small differences in key measures of work output between the 2006 and 2007 Premiership Seasons (Table 11). There was a small reduction in total playing time between seasons, with a small reduction in time spent under 6 km/hr (walking). Small increases were observed for average speed and in the exertion index per minute measure of intensity.

## Workloads by Team

Figure 7 highlights the variation in average game workload between the fourteen participating teams for the 2007 season. Primarily, the data indicate that no team maintained a consistently higher workload on a week to week basis than any other team, with the error bars representing the majority of teams having very different workload patterns on any week.

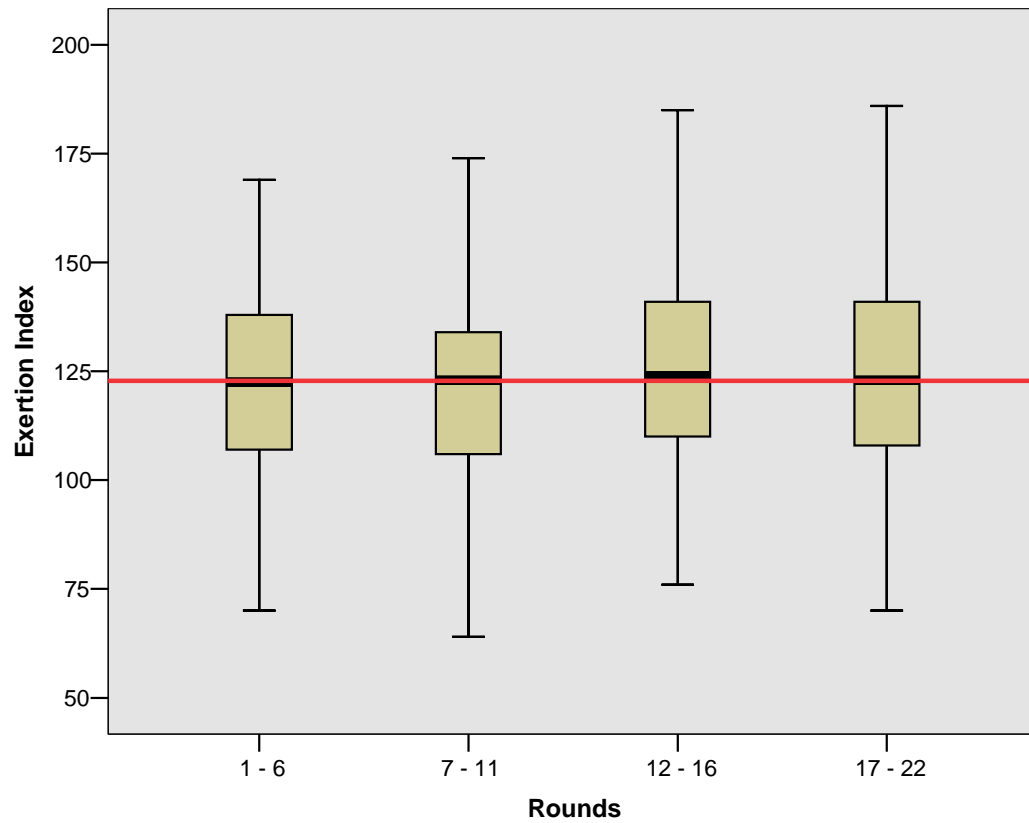


**Figure 7.** Box and Whisker of Exertion Index by AFL Team. The order of teams has been randomised to maintain confidentiality of results. The median value is indicated by the thick black line, the standard deviation by the box, the mean for all teams by the red line, and the range by the vertical error bars.

An inverse correlation ( $r=-0.171$ ,  $p<0.01$ ) was evident between exertion index and the number of wins a team had during the season. This finding indicates that those teams who performed poorly during the 2007 season were required to work harder.

## Workloads across the Season

There was no substantial change in the Exertion Index during the various phases of the season.



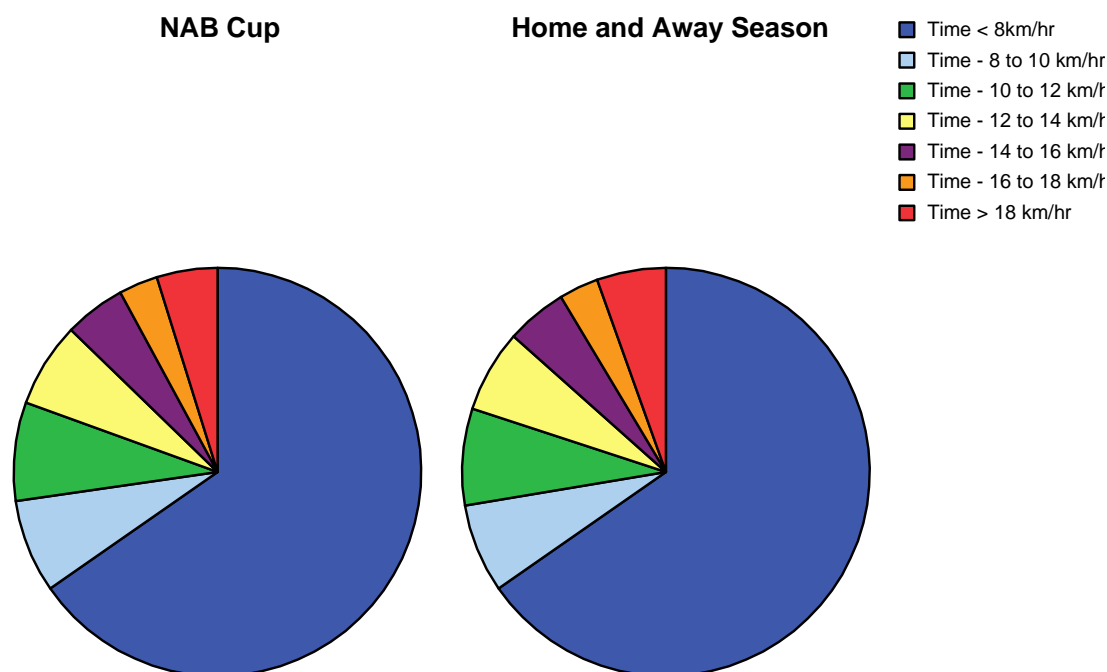
**Figure 8.** Exertion Index over the 2007 Season.

## NAB Cup (Preseason Competition)

**Table 12.** Comparison between work values for the 2007 NAB Cup and 2007 Premiership Season (mean  $\pm$  SD).

	NAB Cup 2007 (n=53)	2007 Premiership Season (n=629)
Total Distance (km)	9.64 $\pm$ 1.99	12.09 $\pm$ 2.04*
Average Speed (km/hr)	7.18 $\pm$ 0.86	7.25 $\pm$ 0.83*
Total Time (min)	81:17 $\pm$ 17:47	100:57 $\pm$ 18:19*
Exertion Index	97.1 $\pm$ 23.5	122.8 $\pm$ 24.3*
Exertion Index per Minute	1.21 $\pm$ 0.22	1.23 $\pm$ 0.23
Steady State Time (min)	18:46 $\pm$ 4:49	23:37 $\pm$ 5:38*
Accelerations over 4km/hr (number)	200 $\pm$ 49	245 $\pm$ 48*

\* = significant difference from NAB Cup data (p<0.05).



**Figure 9:** Pie chart showing the time spent in different workloads for the NAB Cup games, and the Premiership Season.

Several key differences were evident in the data collected in the NAB Cup compared to the Premiership Season. The Premiership Season games had a higher total distance, average speed, volume of steady state running, number of accelerations and exertion

index compared to NAB Cup games. These increases coincided with an increase in playing duration. Taken together there was a similar average game intensity between the NAB Cup and 2007 Premiership Season (exertion index per minute).

The pie chart in Figure 9 shows the similarities in the relative amount of time spent in each speed zone.

### **Key Work Measures**

The exertion index correlated with average speed ( $r=0.59$ ,  $p<0.01$ ), the number of moderate accelerations ( $r=0.73$ ,  $p<0.01$ ) and rapid accelerations ( $r=.28$ ,  $p<0.01$ ), steady state running time ( $r=0.93$ ,  $p<0.01$ ), total distance ( $r=0.93$ ,  $p<0.01$ ) and time over 18 km/hr ( $r=0.81$ ,  $p<0.01$ ).

## **Discussion**

### **Comparisons between 2007 and 2006 AFL seasons**

The overall workload (exertion index) was similar in the 2007 Premiership Season compared with 2006. However, players spent less time on the field (shorter playing duration than in 2006) and recorded a substantially higher game intensity. This GPS data shows a 4.3% increase in exertion index per minute and 5.9% increase in average speed. This confirms the widely held notion that the physical demands of AFL football continues to increase.

This shows a substantial change in player demands even when compared with the previous season (2006). Players are now required to work in shorter periods at an increased intensity. This finding has implications for the physical preparation of players and also tactical considerations in rotating players on and off the bench during AFL games.

A change in the movement pattern profile of the game accompanied the increased playing intensity. The 2007 results show fewer walks and more frequent efforts above 14 and 16 km/hr. The length of efforts above 15 km/hr was also substantially greater.

Not surprisingly, the changes in the movement pattern profile also coincided with less time spent walking, and more time at running speeds between 14 and 18 km/hr. With walking making up such a large percentage of overall game time, the reduction in playing time meant less walking by players.

While a moderate linear relationship shows that as exertion index increases so too does possessions, the team data showed that harder working teams are not the most successful. The combination of these two relationships indicates that harder working teams may get more possessions but this does not necessarily translate into winning games. Further investigation is required to determine the underlying nature and implications of these associations.

### **Comparison between Positions**

The physical demands of different playing position vary substantially. Nomadic players (players who were not considered fixed forwards or fixed defenders) had an 11% higher exertion index but less time on the field than fixed position players. Taken together (higher EI and less playing time) the exertion index per minute was 24% higher for nomadic players. The substantially greater demands for nomadic players would seemingly require very well developed levels of fitness (endurance, speed-endurance, repeated sprint ability and speed).

### **Rotations**

The number of player rotations in AFL football has increased substantially in the last 3 or 4 years (data not shown). One of the key reasons for rotation is to rest players to facilitate a higher intensity upon return to the field. The trend of an increased number



of player rotations to maintain a higher intensity is substantiated with a moderate correlation between the number of rotations and exertion index per minute.

Players who were rotated more regularly in 2007, not surprisingly spent less time on the field. It would appear that AFL clubs are making effective use of the interchange bench to rest nomadic players. Clearly, players need effective conditioning to maintain high levels of intensity on the field and then recover quickly on the interchange bench. The operation of the interchange bench would presumably involve both physical and tactical considerations.

### **Workloads between AFL Venues**

There is much debate on the relationships between ground size, physical and tactical demands, and team performance. Analysis of the 2007 GPS data indicates there was not a substantial relationship between ground size and key physical workload measures.

### **Workloads across the Season**

This study analysed changes in workloads across the 22 rounds of the Premiership Season to determine if there were changes between the early, mid, or late season phases. With many teams timing their preparation to hit peak form in the later part of the season, the researchers were curious to determine if workloads increased, or conversely, if fatigue was becoming a factor. Analysis showed that there were no substantial changes in workload which confirms that AFL football is dynamic and challenging throughout the entire season.

While individual team workloads may have varied throughout the season, this data indicates that to perform well physically, a player, and team, should maintain a high level of workload across the full season. This is based on game workload only and the prescription of training to sustain the competitive workload may vary across the season.

### **Workloads between Teams**

There was variation in workloads between the AFL teams studied through the 2007 season. The key finding here is the moderate inverse correlation between a team's exertion index and the number of wins during the season. At face value the more successful teams undertook less work. Two possible explanations are: (i) successful teams were more efficient at transferring or converting work into successful outcomes (scoring); and (ii) losing teams were required to chase harder when defending or were less efficient in attack. Additionally, cumulative fatigue encountered from several weeks of high workloads might contribute to the losses encountered by some teams.

This scenario was highlighted in one example in 2007 where Team A beat Team B by over 20 points, despite Team B averaging 5% more work (exertion index) across the game in the analysed player data. This is just one example of this in the 2007 season where 5 players from each team were analysed.

These results indicate that the outcome of a game is not solely dependant on a player's underlying fitness or degree of physical effort or work output, but that tactics, skill execution and efficiency clearly play a role in the outcome of a game.

## **NAB Cup**

There were substantial differences in the physical demands (movement patterns) of the NAB Cup and the Premiership Season in 2007. The key difference is the lower volume of load undertaken in NAB Cup games. While the intensity is similar (exertion index per minute), the playing duration is less, and therefore the total exertion index is lower.

The lower volume of work may relate in part to teams not getting players to undertake full playing loads in the pre-season. The similarity in game intensity between the two competitions shows that teams and players can use the NAB Cup as a specific preparation for the Premiership Season.

Other differences between these two competitions that could influence the physical demands include:

- The high ambient temperature that some NAB Cup games are played in;
- The differing rules between the two competitions;
- The aspirations of participating teams in the NAB Cup: some teams seemingly use the NAB Cup to prepare for the Premiership Season while others are more focused on the NAB Cup itself;
- Player quality: younger less experienced players are often used in the NAB Cup.

## **Key Work Measures**

The researchers established the exertion index as a unique measure of quantifying overall game load in 2005. The 2005 and 2006 GPS research reports showed that exertion index provided a useful representation of game load as it correlated highly with key workload measures.

Exertion index proved again to be a useful measure of overall workload in 2007. The researchers recommend that the exertion index be used as a single indicator of overall game load for use by AFL clubs, sports scientists and academic researchers.

The exertion index applies an exponential weighting to single second speed samples, as well as the average of 10 second and 60 second speeds. This approach ensures that both short sharp efforts and long continuous efforts are weighted appropriately to reflect workloads regardless of playing style. This is thought to overcome the limitations of many of the previously used exertion indexes that were based primarily on intensity at the exclusion of duration.

## Conclusions

The overall playing demands of the 2007 Premiership Season were broadly similar to those of 2005 and 2006.

The main difference in physical demands and movement patterns was a higher game intensity in 2007 compared with 2005 and 2006. While the overall workload (represented by the exertion index) was similar in 2007, the playing time (duration) was substantially lower and the game intensity (exertion index per minute) substantially higher (a 4.3% increase in exertion index per minute compared with 2006). Players spent less time walking and more time at 'tempo' speeds between 14 and 18 km/hr in 2007. It will be interesting to see if the relative intensity (exertion index per minute) continues to increase in the coming AFL seasons.

The researchers observed an inverse relationship between the success of a team (assessed from the number of wins in the season) and the player workloads (exertion index). This relationship showed that teams who won more games were able to do so with a lower workload, indicating that the success of a team appears to be based more on their efficiency than their absolute workload. It is also possible that unsuccessful teams expended a substantial amount of energy chasing opponents when in defence or were wasteful when in possession. Cumulative fatigue encountered from several weeks of high workloads might contribute to the losses encountered by some teams.

Physical preparation for the Premiership Season is always a debatable topic, especially when it comes to the effectiveness of the NAB Cup competition. This research has shown that NAB Cup games can be a useful means of preparing for the intensity of Premiership Season matches, as game intensity in both competitions was similar.

It is also important to note the value of the exertion index as a single variable measure of overall game load. The exertion index correlated moderately with all key workload variables underlining its utility as a useful accurate measure of overall running-based load in a game.

Clearly player workloads must be viewed in light of motivational, tactical and skill execution elements of AFL football.

## Future Directions

The continuing developments in performance monitoring technology are likely to offer AFL teams an advantage over teams that are less responsive to these new developments.

Several key technologies are displaying potential in this area:

- Live monitoring – the ability to track player speed and heart rate during both games and training. This feature has the potential to assist support staff in making decisions when to stop training drills, and timing of rotations in games.
- Accelerometers – offering the ability to look at fine movements in three planes, accelerometer data could assist in areas such as injury management, monitoring of physical impacts and action tracking.

The value of these developments is emerging. However, further development is required before use in the AFL will be commonplace. For these clubs, deeper investigation into the use of current technology may prove beneficial. Many clubs might find it problematic to use new monitoring methods when current methods are not being utilised to their maximum capacity. Methods of maximising use of current technology include:

- Action synchronisation – overlaying GPS speed data with possessions, scoring, and other game activities will facilitate integration of GPS monitoring with game demands, activities and outcomes. This work will further enable associations between player effectiveness and physical workload to be investigated.
- Period profiling – with much of the focus currently on the overall demands of the game, often little attention is given to key game aspects. Further investigation is required to determine what occurs in key aspects of the game, for example, what physical demands occur in the 2 minutes either side of a player obtaining a possession.
- Load management – many teams have effectively used GPS to monitor game load. The next step is to consistently monitor the running-based load of players during both training and games to generate a comprehensive workload profile.

## Attachment A: GPS Analysis Definitions

### Work

**Total Distance:** Measures the total distance travelled during the playing period. Measured in kilometres.

**Average Speed:** Total distance divided by total playing duration in hours. Measured in  $\text{km}\cdot\text{hr}^{-1}$ .

**Total Time:** The total on field playing duration. Measured in minutes.

**Exertion Index:** Exertion index is a quantifiable level of physical load developed by FitSense Australia. This measure allows a relationship to be drawn between game load, fatigue, and the total load between players. The exertion index used to assess GPS data in this project was based on the sum of a weighted instantaneous speed, a weighted accumulated speed over 10 seconds, and a weighted accumulated speed over 60 seconds. This ensures both short sharp efforts, and long sustained efforts are analysed equally. The weighting is based on a polynomial relationship in which high speeds achieve a higher exertion value than lower speeds. Exertion index is measured in arbitrary units.

**Exertion Index per Minute:** This is a measure of game intensity. It is determined by dividing exertion index by playing time.

**Efficiency:** A measure of the work requirements for game involvement and game impact. Measured by dividing exertion index by total number of possessions.

**Maximal Speed:** The maximal speed reached for a one second sample period. This is likely to be lower than the actual maximal speed achieved by the player due to the sampling rate and resolution of the GPS system.

### Movement Pattern Profile

**Surges above/below a Specified Speed (# times  $>/< x \text{ km}\cdot\text{hr}^{-1}$ ):** The number of times the player goes from below (above) this speed to above (below) this speed. Gives an indication of the intermittent nature of the session, and the intensity at which speed peaks occur.

**Number of Accelerations (Acceleration  $> x \text{ km}\cdot\text{hr}^{-1}$  in 1sec):** The number of times the speed increases by more than  $x \text{ km}\cdot\text{hr}^{-1}$  in a 1 second time period. This gives an indication as to the accelerations undertaken and how frequently these occur. Accelerations are categorised as moderate ( $4 \text{ km}\cdot\text{hr}^{-1}$ ) or rapid ( $10 \text{ km}\cdot\text{hr}^{-1}$ ).

**Number of decelerations (deceleration  $> x \text{ km}\cdot\text{hr}^{-1}$  in 1sec):** The number of times the speed decreases by more than  $x \text{ km}\cdot\text{hr}^{-1}$  in a 1 second time period. This gives an indication as to the decelerations required and how frequently these occur. Decelerations are categorised as moderate ( $4 \text{ km}\cdot\text{hr}^{-1}$ ) or rapid ( $10 \text{ km}\cdot\text{hr}^{-1}$ ).

**Longest Continuous Time above a Specified Speed ( $LCT > x \text{ km}\cdot\text{hr}^{-1}$ ):** The longest period of time the player stays above this speed, without dropping below this speed. Time is recorded even when the player enters a higher speed zone. Provides an indication of the longest continuous effort at varying speeds.

**Time at steady state  $> 8 \text{ km}\cdot\text{hr}^{-1}$  (Steady State Intensity Time):** Any time at a speed above  $8 \text{ km}\cdot\text{hr}^{-1}$  where the players' velocity does not alter by more than  $1.5 \text{ km}\cdot\text{hr}^{-1}$  within a 1 sec sample period. This gives an indication of time spent at continual running speeds.

### **Time in Speed Zones**

**Speed Zones ( $x - y \text{ km}\cdot\text{hr}^{-1}$ ):** Time spent between the speeds of  $x$  and  $y \text{ km}\cdot\text{hr}^{-1}$ . Provides information on the dispersion of speed throughout the session.

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